Headquarters U.S. Air Force

Integrity - Service - Excellence

Joint Cost Schedule Model (JCSM)

Recent AFCAA Efforts to Assess Integrated Cost and Schedule Analysis

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Outline

- **Background**
- **JCSM in Action**
  - **Establishing a budget from our Independent Cost and Schedule Predictions**
  - **Analyzing impact of schedule acceleration**
  - **Quantifying potential cost impact of a schedule slip**
- **Summary**

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Two Big Questions

How do we establish a budget from our independent cost and schedule predictions?

How much schedule can we accelerate and maintain a target confidence level?
How much does this cost?

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AFCAA Study Findings – Validation of Prior Studies

- **Cost and Schedule are Related**
  - Verified through analysis of USAF and NASA space programs
- **Independent Cost and Schedule Distributions can be Joined**
  - Several techniques
  - All use marginal distributions with correlation as the enabler
- **Joint Confidence Level (JCL) Metric can be Generated via Statistical Analysis**
  - Generated from combination of cost and schedule uncertainty analysis
  - Identifies cost-schedule range to meet combined objectives
  - Used to generate iso-curves (JCL Frontiers)
- **Joining of Right Skewed Distributions exhibits Specific Behavior**
  - Cost growth as a function of schedule growth typical follows a power form
  - Cost is conditional to schedule
  - Cost growth accelerates as schedule slips past the mean

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AFCAA Study Findings – NEW

- **Joint Cost Schedule Models can be Generated from Parametric Results via correlation of marginal cost and schedule distributions**
  - Analysis indicates correlation range is between 40-80% for Space Vehicles
  - Conditional cost probabilities and JCL value dependent on correlation
  - Mean of marginal cost and schedule distributions not impacted by correlation

- **JCSM Results Provide Valuable Additional Insight**
  - Identifies minimum cost for a specific schedule, and vice versa
  - Supports calculation of conditional costs through regression analysis of cost/schedule scatter plot data, underlying **Cost/Schedule Inertia Path**
  - Allows calculation of JCL metric and resultant **Iso-Curves (JCL Frontier)**

- **Cost Penalties for Schedule Changes can be Calculated**

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Establishing a Budget from our Independent Cost and Schedule Predictions

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How does Estimating Community do It?

- **Cost set at a target confidence level and phased over a target schedule date**
  - *"Budgeting to at least the mean of the distribution or higher is necessary to guard against potential risk."* - GAO Cost Estimating and Assessment Guide, March 2009
- **Mean cost phased over mean schedule**
- **Cost and schedule obtained from a target Joint Confidence Level, and phased accordingly**
- **Top-down budget**

Study: Define Method that Complements ICE Process

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Case Study

- **FireSat Example -**
  - Hypothetical Unmanned Space Mission
  - Defined in SMAD and used in AFCAA Cost Risk and Uncertainty Handbook
- **Cost and Schedule Point Estimates**
  - System Cost: $229,635 (BY2011$K) ~ 21% Cost Confidence Level
  - Launch Date: 3/31/2018 ~ 40% Schedule Confidence Level
    - SDD to Launch Dura[illegible]
- **Risk Analysis Resul[illegible]**

	Point Estimate	Confidence Level	Mean	Std. Deviation	Coefficient of Variation (CV)
System Cost (BY2011$K)	$ 229,635	21%	$302,050	$ 92,230	0.3053
SDD to Launch Duration (months)	78	40%	82	11	0.1360
Launch Date	3/31/2018	40%	7/19/2018		

	Cumulative Density Functions										
	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Cost Uncertainty Results - BY2011$K	$185,764	$205,141	$227,010	$248,146	$ 265,436	$285,392	$307,221	$ 334,113	$368,178	$416,615	$469,858
Schedule Uncertainty Results - Months	65	68	72	75	78	81	83	87	90	96	101
Schedule Uncertainty Results - Finish Date	3/3/2017	6/6/2017	10/4/2017	1/7/2018	3/31/2018	6/21/2018	9/15/2018	12/18/2018	4/15/2019	10/6/2019	3/7/2020

Question: How to Budget to the Mean?

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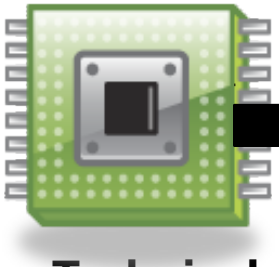
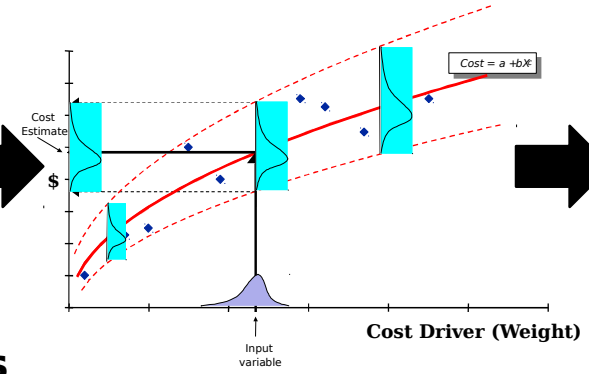
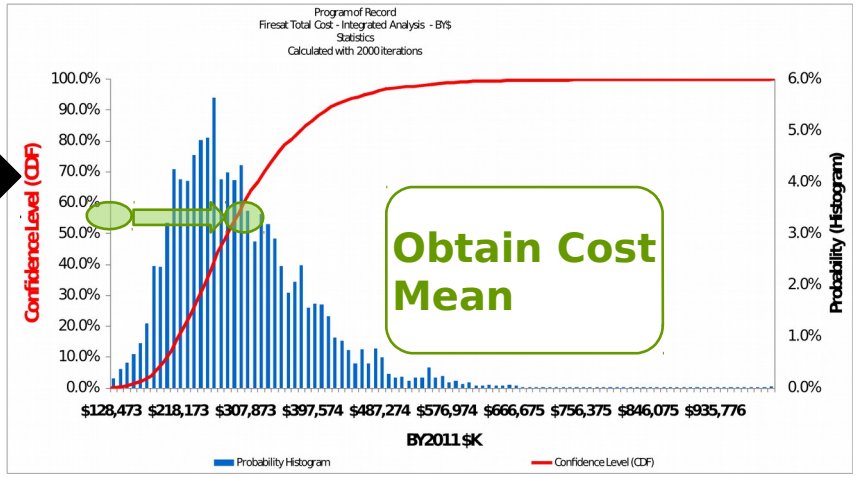
ICE Cost and Schedule Approach



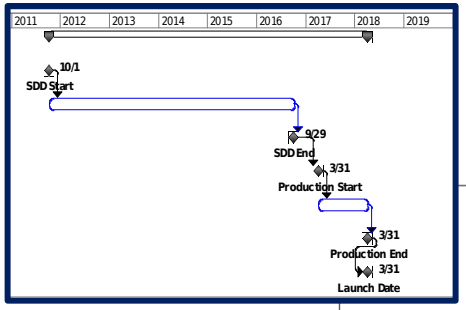
Technical Parameters

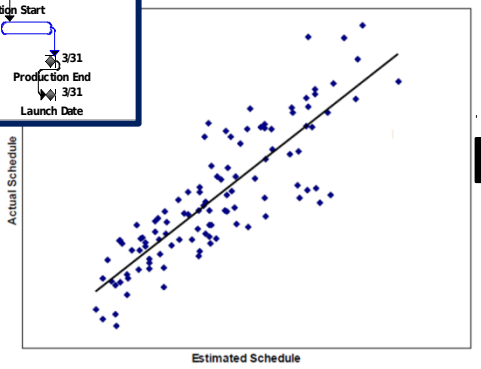


CERs / Cost Model

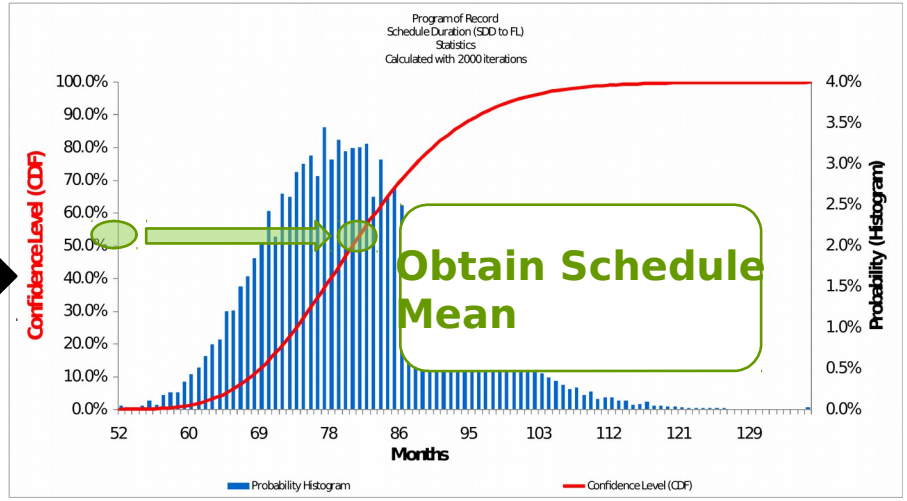


Cost Uncertainty Analysis





SER/ Schedule Risk Analysis



Schedule Uncertainty Analysis

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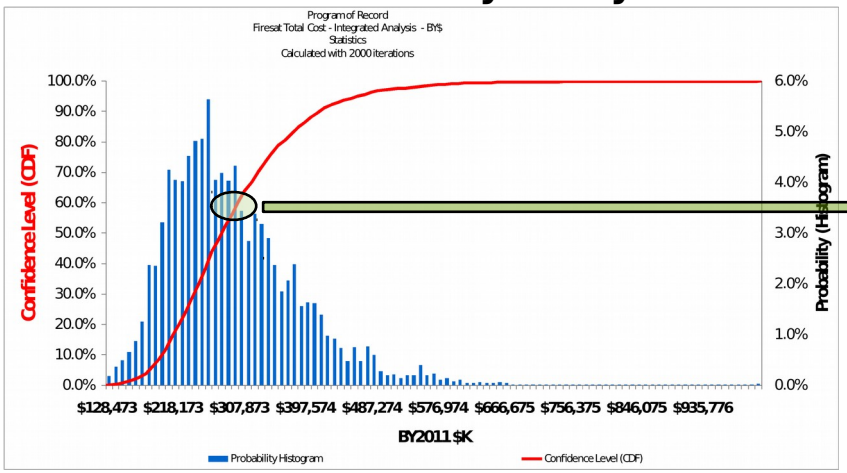
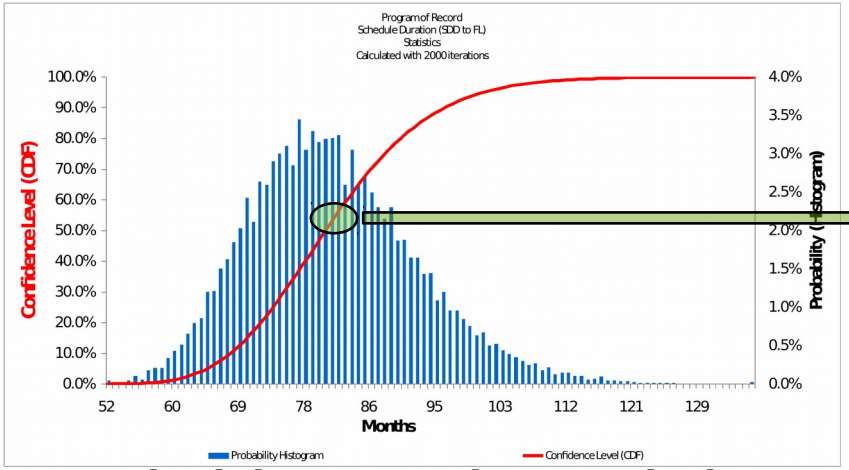
Setting the Mean Budget

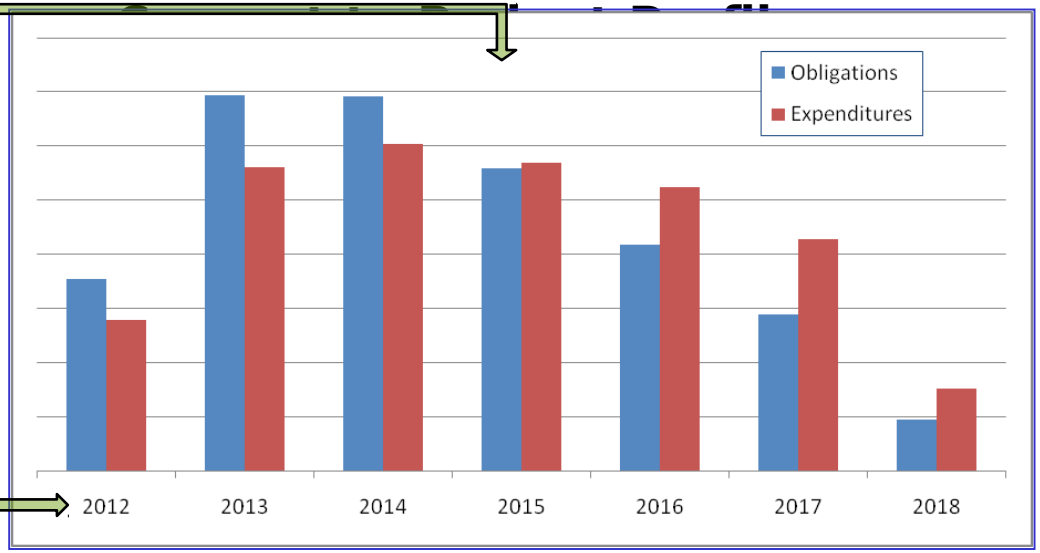
Cost Uncertainty Analysis





Schedule Uncertainty Analysis

1. **Find Mean Cost and Schedule**
2. **Determine Expenditure Profile**
3. **Phase Expenditure over Schedule**



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Building the Joint Cost Schedule Model (JCSM)

- **Estimated Effort (Cost) and Duration (Schedule) are Modeled with Respective Uncertainties**
- **Correlation Implemented between Cost and Schedule Distributions**
- **Simulation Analysis Conducted to Obtain Cost/Schedule Pairs**
- **Joint Confidence Level (JCL) Obtained from Resulting Scatter**
  - Cost and Schedule confidence level calculated from data and identification of cost/schedule target pair
  - JCL is the percent of iterations that are less than and equal to both the cost and schedule target pair

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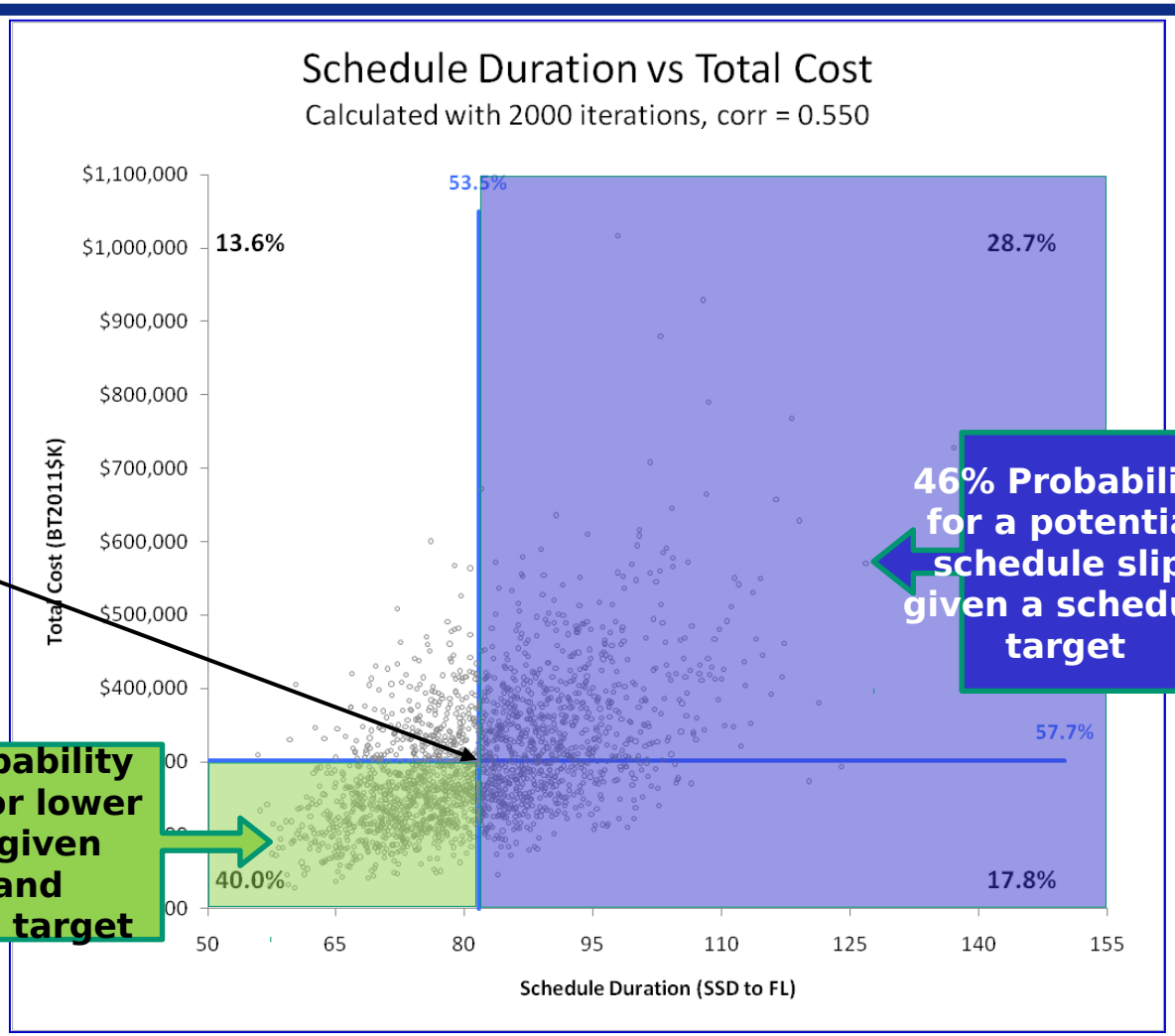
What is the JCL Metric?

Mean schedule, mean cost value

Marginal view… is at 54% schedule confidence, 58% cost confidence, and 40% joint confidence



40% Probability to be at or lower than a given cost and schedule target

46% Probability for a potential schedule slip, given a schedule target

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How Much Schedule can I Possibly Accelerate to Maintain a 40% JCL and What is the Dollar Impact?

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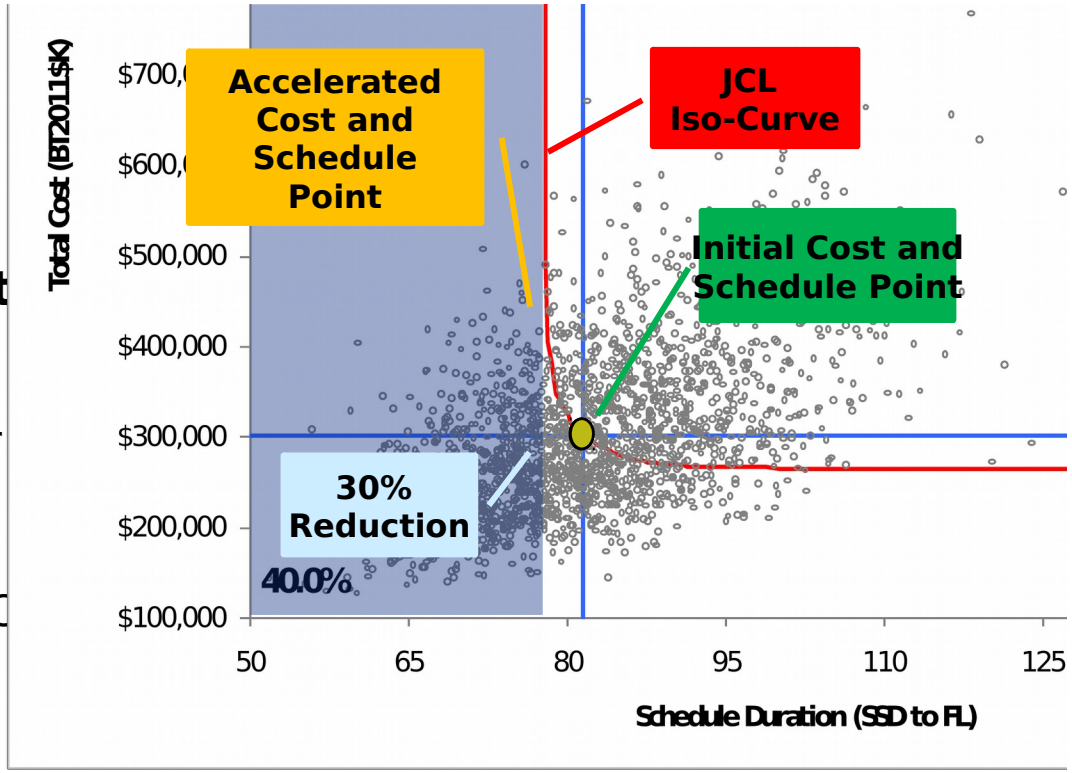
JCSM in Action – Schedule Acceleration

1. **Generate Scatter Plot from Marginal Distributions for Cost and Schedule and Relevant Correlation Value**
2. **Plot Project Plan's Cost and Schedule Value (Mean / Mean)**
3. **Create 40% Iso-Curve**
4. **Identify Schedule Acceleration Limit**
5. **Regression line through Target Value (Inertia Pat**
6. **Identify Cost Impact**
   - JCL at new point much lower
   - Requires Additional Costs to "Buy" Confidence
   - Overall Impact to Maintain JC
     - ~5% Schedule Reduction
     - ~49% Cost Increase



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If I Want to Target a 70 Month Duration What is the Dollar Impact to Maintain a 40% JCL

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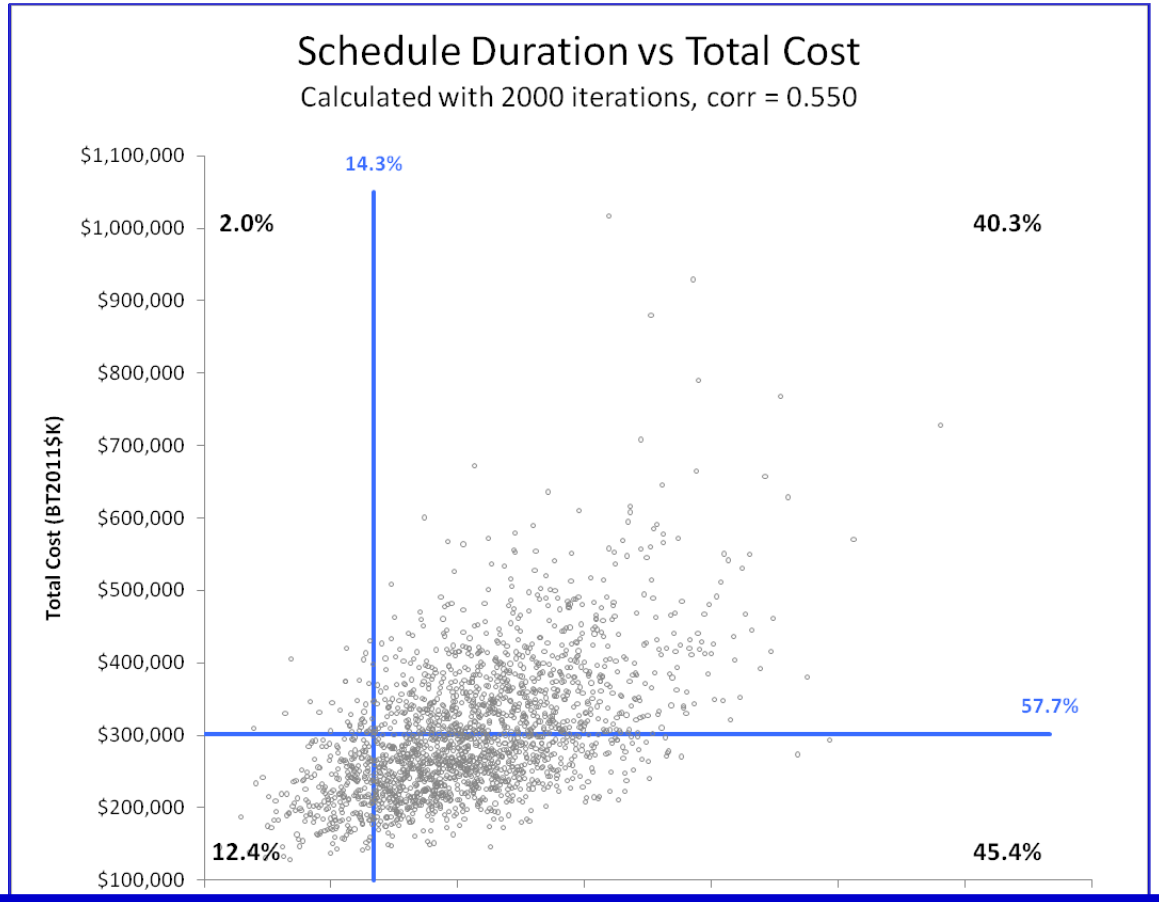
Targeting a 70 Month Duration



Cannot Accelerate Schedule and Maintain Overall Confidence Level Without Adding More Funds

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What is the Cost Impact if my Schedule Slips?

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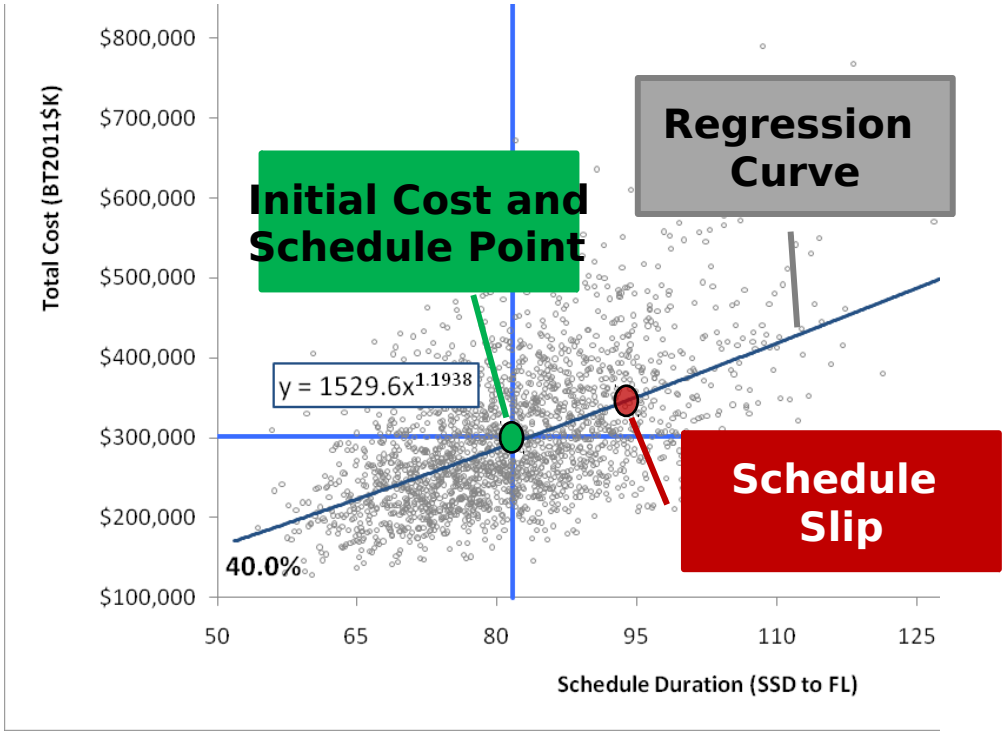
JCSM in Action – Schedule Slip

1. **Generate Scatter Plot from Marginal Distributions for Cost and Schedule and Relevant Correlation Value and plot Project Plan's Cost and Schedule Value**

2. **Run Regression on Scatter (Cost = a + b*Duration^c)**

3. **Translate regression to project cost and schedule**

4. **Determine cost of schedule slip**
   - 12 month slip = $43M (14% cost increase)



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If I Want to Target a 60% JCL What is the Cost and Schedule Target

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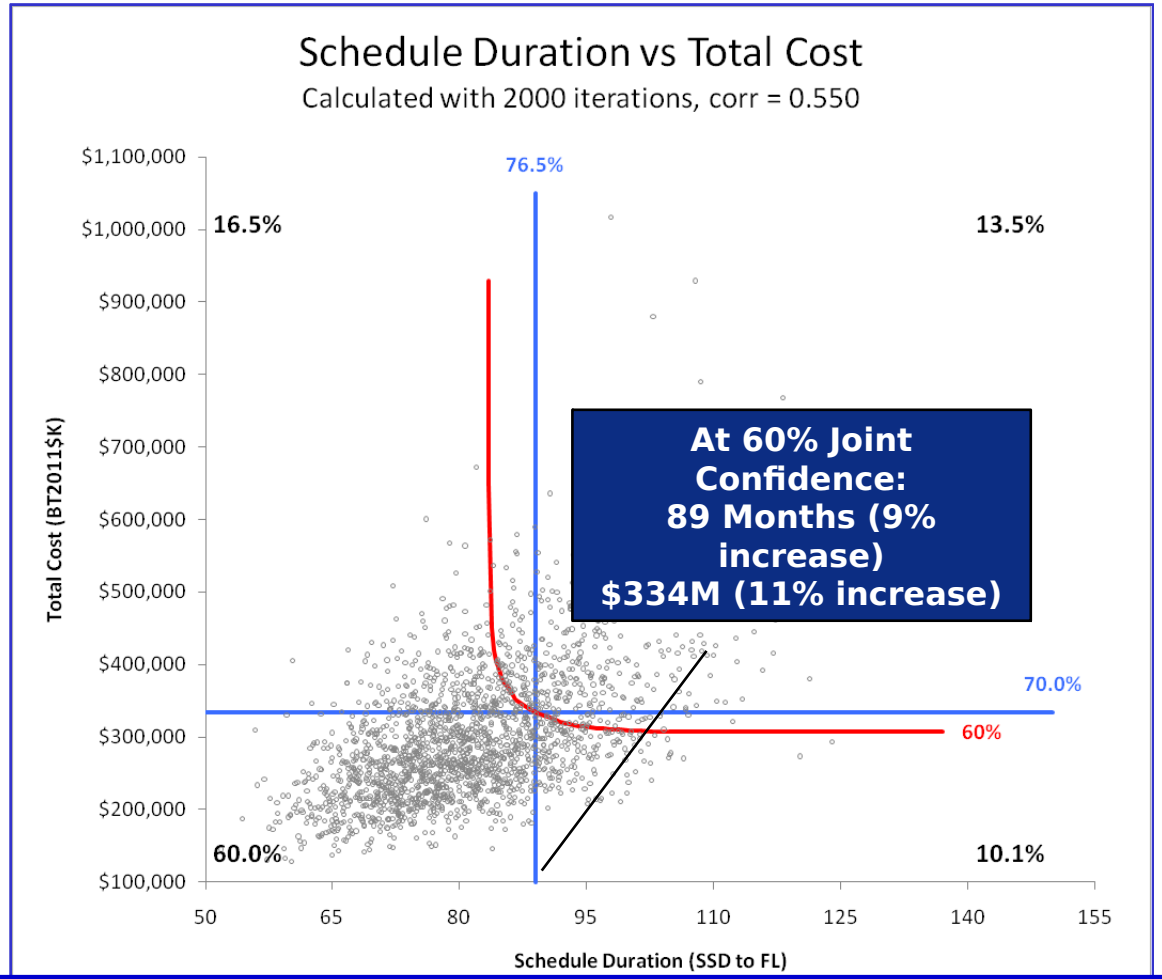
Targeting a 60% Joint Confidence



Cost increases as schedule increases, and so does JCL…

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Summary

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AFCAA Study Findings - Summary

Project Formulation

- **Cost and Schedule are Related**
- **Cost and Schedule Distributions can be Joined**
- **Cost Growth vs Schedule Growth Follows a Power Form**
- **Cost is Conditional to Schedule**
- **Cost Mean – Schedule Mean are not affected by Correlation**

Project Execution

- **Joint Cost Schedule Models Enhance Understanding of a Project's Cost/Schedule Behavior**
- **Cost Penalties for Schedule Changes can be Calculated from JCL Frontier Curves and Project Cost/Schedule Inertia Paths**
- **Impacts of Funding Changes can be Derived from JCSM Results**
  - Change in CCL and JCL values
  - Modeling of Effort Rollover

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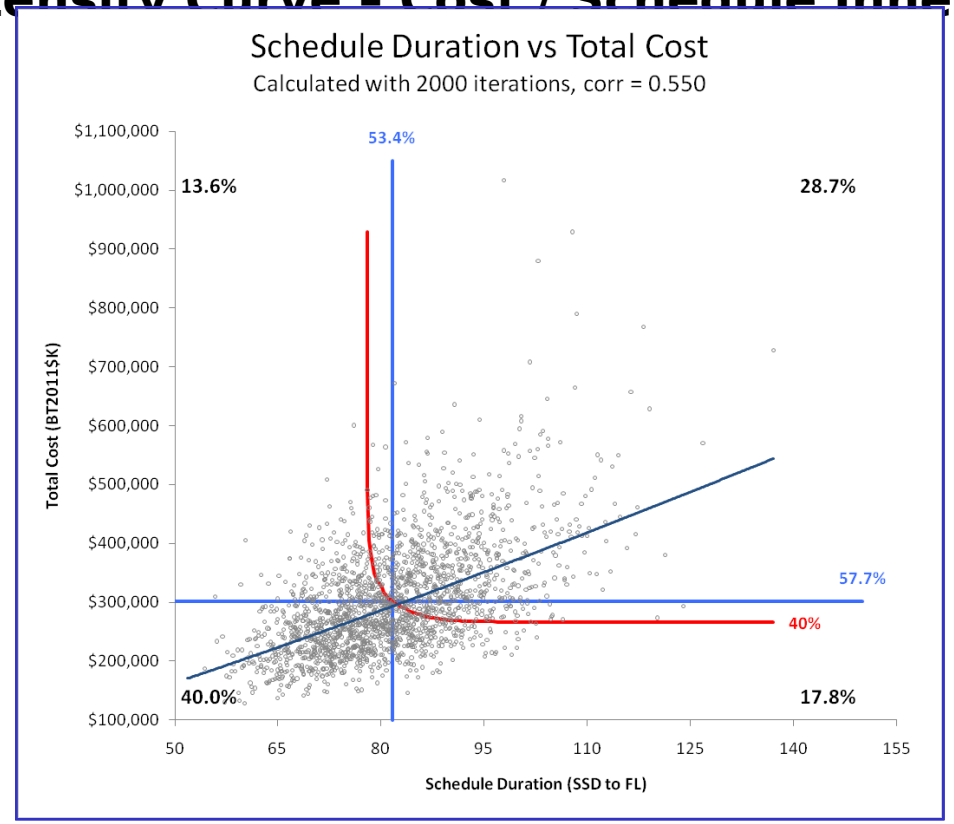
Five Key Tools

1. **Scatter Plot – Determine JCL Value**
2. **JCL Frontier Curve – Identify Cost Penalty for Schedule Acceleration**
3. **Project Intensity Curve – Cost / Schedule Inherent Behavior**



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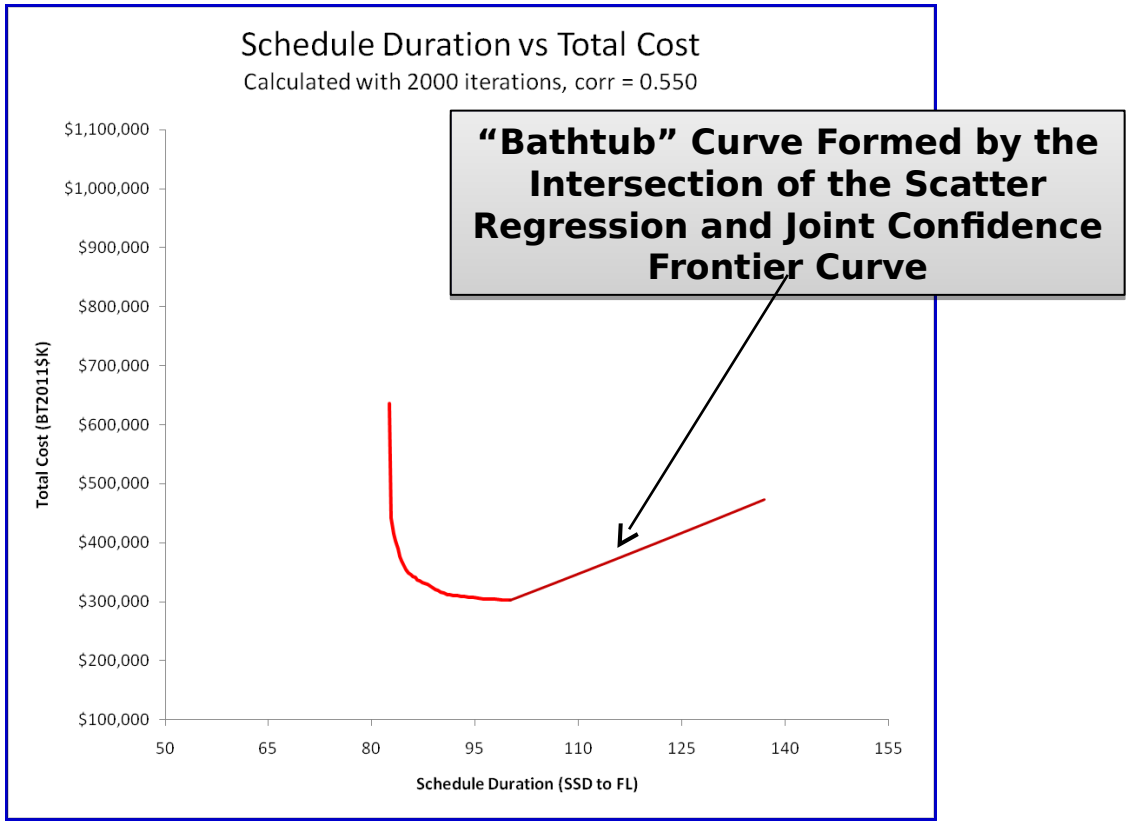
JCSM in Action - Cost Penalty Curves

- **Cost/Schedule Penalty curves can be generated from Frontier Curves and Regression Lines**



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